An Account of an Experimental Release of Marked Juvenile Chinook to Freshwater, Estuarine, and Marine Habitats Near Campbell River, B.C.

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AN ACCOUNT OF AN EXPERIMENTAL RELEASE OF MARKED JUVENILE CHINOOK TO FRESHWATER, ESTUARINE, AND MARINE HABITATS NEAR CAMPBELL RIVER, B.C.

by

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ABSTRACT

Levings, C.D., M.S. Kotyk, T.J. Brown, C.D. McAllister, J.S. Macdonald, U. Fagerlund, and J. McBride. 1984. An account of an experimental release of marked juvenile chinook to freshwater, estuarine, and marine habitats near Campbell River, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 1269: 35 p.

Transport of 140,000 marked chinook smolts (2 to 4 g) by helicopter from Quinsam Hatchery to four release sites near Campbell River (river, estuarine, transition, and marine) was accomplished without major problems. The transport did not unduly aggravate the state of stress already induced during holding in troughs after marking. The furthest site, Deepwater Bay, was about 15 minutes flying time from the hatchery, but air time for the other three treatments was equal to balance the experiment. At Deepwater Bay (marine release) fish were released directly into sea water. The high cortisol levels and enlarged interrenal nuclear diameters noted in these fish in contrast to those at the estuarine site indicate a transitory response to seawater exposure. Nevertheless, there was no evidence of immediate direct mortality due to stress or osmoregulatory shock. SCUBA observations showed the fish schooled and aggregated near surfaces and behaviour was relatively normal. However the marine release fish were exposed to more bird and fish predation. Feeding may have been re-initiated more slowly at the marine site compared to estuarine locations. Mortality of cage-held chinook was highest (est. 9%) at the marine location, as at all other sites mortality <1%. Seawater challenge tests indicated that the chinook were smolted and "ready for sea", but evidence from other sources (caged fish studies and histological data) suggested that smoltification was incomplete. Beach seine data obtained up to 4 days after the releases showed that marine fish did not disperse to the Campbell River estuary. Transition zone fish had the widest apparent dispersal pattern, while estuarine zone fish displayed the most restricted distribution and were only taken at one station outside the estuary.

Key Words: juvenile chinook, estuarine utilization, salmonid transport, stress measurements, experimental release, Campbell River estuary.

RÉSUMÉ

Levings, C. D., M. S. Kotyk, T. J. Brown, C. D. McAllister, J. S. Macdonald, U. Fagerlund, and J. McBride. 1984. An account of an experimental release of marked juvenile chinook to freshwater, estuarine, and marine habitats near Campbell River, B.C. Can. Tech. Rep. Fish. Aquat Sci. 1269: 35 p.

Le transport par hélicoptère de 140 000 saumoneaux quinnats marqués (pesant de 2 à 4 g) de la piscifacture de Quinsam à quatre sites de lâcher, près de la rivière Campbell (en rivière, en estuaire, en site de transition et en mer), s'est effectué sans problèmes majeurs. Le transport n'a pas aggravé outre mesure l'état de stress déjà provoqué par la stabulation en auges après le marquage. La baie Deepwater, le site le plus éloigné, était à environ 15 minutes de vol de la piscifacture mais le temps de vol vers les trois autres sites a été prolongé en conséquence, afin d'équilibrer l'expérience. Dans la baie Deepwater (lâcher en mer), les poissons ont été relâchés directement en eau salée. Les niveaux élevés de cortisol et les diamètres dilatés des cellules interrénales notés chez ces poissons par rapport à ceux mis en liberté en estuaire dénotent une réaction momentanée à l'exposition à l'eau salée. Il n'y avait toutefois aucune preuve de mortalité directe immédiate causée par le stress ou le choc osmorégulatoire. Des observations en plongée ont montré que les poissons se sont rassemblés en banc près de la surface et que leur comportement était relativement normal. Toutefois, les poissons relâchés en mer ont été exposés à une plus forte prédation par les oiseaux et les autres poissons, et leur alimentation a peut-être recommencé plus lentement que chez les poissons relâchés en estuaire. La mortalité des quinnats gardés en cage a été la plus élevée (9%, est.) au site marin; de fait, dans tous les autres groupes, la mortalité a été inférieure à 1%. Des tests d'adaptation à l'eau salée ont montré que les quinnats avaient smoltifié et étaient prêts pour la vie en mer, mais des preuves obtenues d'autres sources (études des poissons gardés en cage et données histologiques) portaient à croire que la smoltification n'était pas complète. Les données générées par des levés à la senne de rivage jusqu'à quatre jours après les lâchers ont démontré que les poissons marins ne se sont pas dispersés vers l'estuaire de la rivière Campbell. Les quinnats lâchés dans la zone de transition s'étaient apparemment le plus dispersés; par contre, ceux mis en liberté en estuaire ont connu la plus petite dispersion et n'ont été capturés qu'à une seule station à l'extérieur de l'estuaire.

Mots-clés: saumon quinnat juvénile, utilisation estuarienne, transport des salmonidés, quantification de stress, lâcher expérimental, estuaire de la Campbell

INTRODUCTION

In 1983 approximately 140,000 chinook smolts were reared and marked at the Quinsam River hatchery and released at contrasting habitats in the Campbell River estuary, the Quinsam River, and Discovery Passage (Fig. 1, Table 1). The objective of the research was to test the smolt to adult survivorship of chinook that were not exposed to the normal sequence of river - estuary - marine habitats. This report provides details on several topics related to the releases. These include transport techniques, results on short-term mortality, growth, feeding, stress, surface and SCUBA observations of released fish, data on sizes and weights of released chinook, and tag codes used for the various groups.

MARKING PROCEDURES

There were 142,257 chinook fry marked and tagged during the period from April 11 to 1^ 1983 under the direction of A. Coburn of the Pacific Biological Station, Nanaimo. These fish were taken from the production stock of Quinsam hatchery. All fish were anaesthetised, marked by clipping the adipose fin and tagged by inserting the appropriate magnetic binary coded wire tag into the nose cartilage. Approximately 35000 fish were tagged for each of the four release zones (river, estuary, transition, marine) with each area represented by 4 separate tag codes (Fig. 1, Table 1).

Fish were then transferred to unpainted aluminum holding troughs approximately 6.1 m x 81 cm x 60 cm, each containing a separate release group and held for at least 2 days before release. On the day prior to release 300 fish from each trough were sampled to collect data on tag retention (Table 2). Total number of fish marked per tag code, along with the number of mortalities from each code, the number removed for various studies and the total number released are shown in Table 3. On April 21, about 2 h before fish transport began, approximately 150 fish were sampled from each trough for length and weight analyses (Table 4).

RELEASE PROCEDURES

A Bell 212 helicopter and two 1364 L monsoon buckets were used for transport and release of the fish. The buckets had walls of semi-collapsible rubber with two pneumatically controlled doors at the bottom. An oxygen cylinder was attached to each bucket to aerate the water during transport.

On April 21, 1983, the buckets were placed on a pallet and transported with a fork lift to the holding troughs for filling with water and loading of fish. When a bucket was filled with water and fully aerated, fish were herded to one end of the trough and dipnetted into the monsoon bucket. After 15000 - 17000 fish were loaded, a forklift moved the bucket approximately 50 m to be attached to the helicopter and transported to the release zone. While the helicopter was enroute, the second bucket was loaded. On the first release at a site, the helicopter set the bucket down on a beach near the release area, where 140 to 180 fish were transferred to holding cages. These fish were carried to the cages in 22 L plastic buckets, containing surface water collected nearby, by foot, truck and boat. Maximum transport time from helicopter bucket to cages was 10 minutes. Fish were counted from buckets to cages using a nylon dipnet. The helicopter moved the monsoon bucket to the drop site, where it was lowered into the water. After the release doors were opened, the bucket was slowly lifted to release the fish. On the second drop at each site the helicopter did not stop on the beach but flew directly to the release site. At the river, estuarine and transition sites the helicopter either flew in circles or hovered in place (Fig. 1) until each load of fish received approximately the same amount of air time as those destined for the marine zone (Table 5).

Two problems were encountered at the beginning of the operation. On the first attempted lift it was discovered that the helicopter could not lift the bucket with full fuel tanks. Therefore the helicopter could only transport the fish with a half load of fuel, resulting in three refueling stops between drops. On the first drop to the marine zone, the pneumatic hose controlling the release doors was not properly connected to the bucket resulting in air being pumped into the bucket and preventing the release doors from opening. This resulted in about 10% of the fish being returned to the hatchery after the helicopter refueled. These fish were left in the bucket while the second one was tested to ensure its proper operation. They were then loaded, along with the remaining fish destined for the marine zone, into the second bucket and transported to the drop site. Upon return of the helicopter, the first bucket was properly connected and tested. The remaining releases to each of the zones were conducted without any problems.

RELEASE OBSERVATIONS

(i) Predator activity:

River - no avian or mammalian predators were recorded at this location.

Estuary - very few avian predators were observed at the time chinook were released at this site. Five mergansers, 1 bald eagle and about 20 glaucous-winged gulls were seen along the reach of Campbell River approximately 1 km downstream from the release site. One harbour seal was observed.

Transition - no avian or mammalian predators were observed at this location.

Marine - no avian or mammalian predators were seen on first drop. Approximately 175 - 250 Bonaparte gulls were actively feeding after second drop, presumably on herring which were spawning in the area. Buffalo sculpin stomachs caught by beach seine within 3 hours of the release contained chinook fry (Table 6).

(ii) Fish behaviour:

River - no direct observations were recorded at this site. Movements of marked chinook through the counting fence at Quinsam are shown in Table 7. The majority of the fish moved downstream within a day of release.

Estuary - visibility was relatively poor at the time of release and so only fish swimming within about 25 cm of the surface could be seen. A school of about 200 chinook fry was seen at the site 10 minutes after the release but after approximately 1/2 hour none were observed.

Transition - only about 10 fish were observed at this site immediately after release, although visibility was considerably better than at the estuary site. A strong ebb current (est. 2-3 kts) was flowing northward, which possibly moved the smolts into Discovery Passage.

Marine - More detailed observations were made at the marine site than at other sites because problems in osmoregulation were anticipated due to high salinity. Observations were made for one hour after both releases by an observer in a small boat and by two SCUBA divers. Most of the divers' time was spent along the shore (approx. 0.5 - 3 m of water) observing individual fish and their potential predators and prey. However, 15 minutes was spent diving along an offshore ledge in 12 - 14 m of water. The horizontal visibility in the water was 10 m, the temperature 9°C and the salinity 30‰. Immediately after the release, fish were observed congregating around large rocks, a piling and even the divers. They formed loose schools in the top two metres of the water column and appeared lethargic and disoriented for about 25 minutes but they did display avoidance behaviour when a diver made a sudden movement. Some of the second group of fish released appeared more lethargic, possibly because they had been left over from the first release. Within 15 minutes of each release many fish were seen among the eelgrass and algae in the shallow subtidal zone or in schools (approximately 25-50 fish) along the rock cliffs on either side of the embayment. They were observed at these locations for the rest of the one hour observation period after each release. Twenty-five minutes after the release no fish could be seen by the observer in the boat. Divers noticed that the fish began to feed on a large bloom of calanoid copepods within 25 minutes

of the release. However, one chinook was seen feeding on a wood chip.

Fifty minutes after the release many fish were observed in 0.5 m of water or less along the beach. At the same time no fish were observed near the bottom of an offshore drop-off (12 m +). During both 1 h observation periods there was no evidence of salmon mortality at the release site. However, one dead hatchery chinook was found a day after the release 1.4 km to the south-west of the release site. There was a flock of Bonaparte gulls (175-250) near the release site during the second release, feeding on either herring, herring spawn or juvenile salmonids.

To conclude, observations from small boats and with SCUBA provided valuable information about the behaviour of salmon during and shortly after the releases. Chinook salmon released into the marine environment avoided deep, open water in favour of the refuge provided by eelgrass, Agarum sp., rocks, pilings and rock cliffs in the shallows. Those fish near the bottom were potential prey for large sculpins particularly during the period after the release when the salmon were lethargic. Those that schooled near the rocky shores may have quickly dispersed out of the bay along the shore and become potential prey for gulls. Release of large numbers of fish may attract predators although this was not apparent at the other sites. Fish that appeared lethargic after the second release may have been those that were left over from the first release. Little mortality was observed and some fish were feeding 25 minutes after the release.

(iii) Immediate dispersion:

Marked fish were recovered by intensive beach seining over the period April 21 to 25 at stations shown on Figure 2. Seining on April 21 was most intensive at the area of the marine release. Detailed data are presented elsewhere (Brown et al. 1984). Generally recoveries were lower than expected, suggesting that residence time at all four locations was relatively brief. The recapture pattern and presumed migration routes of the various marked groups are shown in Figs. 2 to 5.

Marked fish from the marine release at Deepwater Bay did not disperse back to the estuary (Fig. 2). Some river fish moved to the estuary within a day and a few dispersed immediately to the Seymour Narrows area (Fig. 3). Transition zone fish showed the widest apparent dispersal pattern, and were recovered at several stations in the Seymour Narrows area (Fig. 4). Only 3 estuarine release fish were recovered in Discovery Passage (Station 21) (Fig. 5). This group had the most restricted distribution of the four groups released during the time period under consideration. Most estuarine release fish were recaptured in the estuarine zone (i.e. behind Tyee Spit), but there was significant mixing of transition and river release fish in this area (Chang et al. unpublished data).

(iv) Feeding data from recovered fish

Since it was of interest to determine if released fish showed spatial or temporal differences in feeding habits, stomach analyses were conducted on juvenile chinook recovered by beach seine during April 21 to 25. Marine zone fish were not feeding heavily 4 days after liberation, compared to estuary fish which showed a progressive increase in stomach contents as a percentage of body weight (forage ratio). Estuary fish also had a marked decrease in percentage of empty stomachs (Table 8), whereas the proportion of non feeding fish in the marine release was relatively constant.

CAGE RESULTS

Between 140 and 180 fish were removed from the helicopter bucket at each zone prior to the release. About 50 fish were placed in each of three pens (80 cm x 50 cm x 60 cm; with 1 cm stretched mesh) floating vertically and supported at the water surface with polystyrene foam. These pens were located to expose the fish to water typical of the release environment. The cages at the river site were lashed together and moored at the river bank near the head of a pool approximately 250 m upstream of the hatchery on the Quinsam River and very close to the release site. The estuarine cages were tied in covered moorage within the Freshwater Marina (Fig. 1). They were exposed to slight to moderate currents and reduced light. The cages held in the transition zone were lashed together and anchored in a channel approximately 650 m northwest of the mouth of the river, very near the release site (Fig. 1) and close to Painters Lodge resort. This channel is subject to strong tidal currents on both the ebb and flood tides. The cages in the marine zone were held at Browns Bay, approximately 2 km southeast of the Deepwater Bay release site (Fig. 1). These were tied to a boat slip at a marina, and were subjected to moderate currents and natural light levels. Salinity and temperature measurements were made regularly using either an American Optical refractometer along with a hand held thermometer or by using a Beckman RS-5 salinometer. The fish were fed daily with 2.38 mm diameter Oregon Moist pellets. The fish were held for 21 days, some being removed for a variety of tests, including stress observation, length-weight determinations, and acclimation tests. Observations and sampling times are listed in Tables 9 to 12.

(i) Mortalities:

There were no mortalities at either the river or transition locations, and only one in the estuary. In the marine zone there were mortalities for the first 8 days of the experiment but none occurred after day 9; the total mortality was estimated at approximately 9%. Even though observations and removal of the mortalities were made on a daily basis, the bodies of the dead fish were severely decomposed and/or partially eaten, with some parts such as tail fins and pieces of flesh

missing. However no active predation or cannibalism was observed. Surface salinities ranged from 0.2 to 14.7‰ at the estuarine zone, with ranges from 0.9 to 30.3, and 32.0 to 34.0‰ at the transition and marine zones respectively. Temperatures remained fairly constant with ranges from 8.0 to 11.5, 9.2 to 12.5 and 8.0 to 9.8°C at the estuarine, transition and marine zones respectively. Length and weight measurements of the fish were made after the fish had been in the cages for 21 days (Table 4). Fish in cages at the marine and transition zones increased in length during their 21 day residency (t-test, $p < 0.05$). Differences were not statistically different at the river and estuary zones.

At the end of the experiment it was discovered that some fish were unaccountably missing from the cages. Close inspection revealed holes in three of the cages, one measuring 6 cm stretched in one of the river cages and one hole in each of two of the three cages in the marine zone measuring 4 cm and 3.5 cm stretched.

(ii) Seawater Challenge Tests

Blood sodium testing was performed from April 28 to May 3 to monitor the acclimation of the fish when placed directly into seawater from fresh water. Smolts were removed from a trough before the release and on April 28 from the various cages and taken to Pacific Biological Station, Nanaimo for seawater challenge tests (Clarke and Blackburn 1977). Tests showed that almost all groups challenged with 29§ seawater showed blood sodium levels that were within the "perfect smolt" category (Table 13). Blood sodium levels were <165 milliequivalents mL^{-1} except for the sample from the Quinsam River. Almost all of the experimental groups were therefore physiologically ready for exposure to estuarine or marine conditions, and would have satisfied the criteria for release established by hatchery operators.

(iii) Stress Experiments

The stress response of chinook placed in cages was monitored by measuring two physiological parameters, plasma cortisol concentrations and interrenal cell nuclear diameters (ICND) (Table 14). Cortisol concentrations are known to increase instantaneously in response to stressors in the environment (acute response). In contrast, changes in ICND's develop more slowly and within narrow limits and thus are indicative of more chronic stress. Moreover, both parameters undergo changes during smoltification and transfer to seawater. The latter changes are associated with the role of cortisol in the regulation of Na-K-ATPase in the gills and gut. In addition to these parameters haematocrit readings were recorded as a general indicator of the health of the fish (Table 14).

(a) Plasma cortisol concentrations

An analysis of variance showed that both date of sampling and location significantly affected cortisol concentrations. Differences between individual values within a group of fish were substantial,

resulting in large standard deviations. This, together with the fact that mortalities occurred in only two groups, is a reflection of the large variation between individuals in the response to stress.

High cortisol concentrations (>70 ng mL^{-1}) found in fish sampled at the hatchery indicate that the conditions in the troughs were stressful to the fish. Available information does not allow us to conclude whether the stress was caused by temporary or persistant disturbances of the environment. The transfer to the cage sites, although undoubtedly stressful was nevertheless rapid and consequently did not appreciably increase plasma values further.

In river cages mean cortisol concentrations generally decreased with time of residence. The high values recorded after 2 days suggest that low water level in the river and possible disturbance by beavers at that time induced unfavourable conditions in the cages. This was corroborated by the large ICNDs found, the highest measured at time during the study.

Cortisol concentrations 1 and 2 days after transfer to the estuarine cages were lower than those recorded at any other site. The slight increase of 7 days and the larger increase at 20 days may have been caused by temporary disturbances in the environment, such as moving of boats in the adjacent marina.

Large fluctuations in cortisol concentrations did not occur in the transition zone, but a general trend to lower values with time may be discerned, suggesting that the fish became acclimated to the conditions at this site. The unusually high cortisol concentrations (range 94-370 ng/mL) found in all fish taken after 1 day in the marine cages are consistent with reports showing transient increases in anadromous species during seawater adaptation (Forrest et al. 1973; Strange and Schreck, 1980).

(b) Interrenal cell nuclear diameters (ICND)

As in the case of cortisol data an analysis of variance indicated significant effects of time of sampling and location on ICND. There was also a significant interaction of time and location. It should be noted that any differences in ICNDs between groups were small in comparison with changes known to occur in response to stressors which impair normal body function (Fagerlund et al. 1968; McBride et al. 1981). Duncan's multiple range test of data arranged in appropriate block designs showed that ICNDs of fish held for 20 days in either river or estuarine cages were significantly smaller that those of any other fish. Although the seawater challenge test suggested that the fish were able to maintain osmoregulatory function at the time of the transfer to the test cages, the general decline in interrenal activity between days 7 and 20 noted at all locations may indicate that the fish in fact were not fully smolted until some time after transfer to the cages. This reasoning is supported by the observation that some mortalities occurred after the transfer to the marine cages. Any difficulty in adaptation to the high salinity may have been augmented by the already stressed state of the fish caused by the conditions in the hatchery troughs and the

transport to the cages without an intermediate "recovery period". The significant increase in interrenal activity after transfer to the marine cages is consistent as discussed above, with the known involvement of the interrenal in seawater adaptation (Olivereau 1962, 1966).

The large ICNDs of fish held for 1-7 days in river cages, although similar in magnitude to those of fish in marine cages, may nevertheless have had different origins, namely stress induced by the low water level and/or beaver disturbance at the cage site.

(c) Haematocrits

An analysis of variance showed an effect of location but not of time in cages. However, statistically significant differences were detected only in samples taken after one day's residence in the cages, when haematocrits of fish held in the river and the transition zone were significantly higher than at the two other sites. There was a general trend to increasing values between day 1 and day 21.

(iv) Feeding

Stomach contents were examined from five fish from each of the zones at the middle and end of the cage incarceration period (Tables 14 to 17).

The weight of the stomach contents at the river site increased with time when measured as percent of body weight (forage ratio). The predominant prey were insects. The fish at the estuarine zone showed a similar trend, the predominant prey were insects, gammarid amphipods and sphaeromid isopods. However, the forage ratio for fish at the transition zone decreased with time. Main food items at this location were calanoids, harpacticoids and cumaceans. The fresh-water cladoceran Bosmina sp. was one of the main prey items in the first sampling but not in the second. This could be due to a difference in tidal activities on the different days. The marine zone fish also showed increasing stomach content weight over time, the main prey items being calanoids, harpacticoids and crab larvae.

CONCLUSIONS

Transport of 140000 marked chinook smolts (2 to 4 g) by helicopter from Quinsam hatchery to four release sites (river, estuarine, transition, marine) was accomplished without major problems. The transport did not unduly aggravate the state of stress already induced during holding in troughs after marking. The farthest site, Deepwater Bay, was 12 to 18 minutes flying time from the hatchery, but air time for the other three releases was similar, resulting in comparable treatment. At Deepwater Bay (marine release), fish were released directly into seawater. The high cortisol levels and enlarged interrenal nuclear diameters noted in these fish, in contrast to those at the estuarine site, indicate a transitory response to seawater

exposure. Nevertheless, there was no evidence of immediate direct mortality due to stress or osmoregulatory shock. SCUBA observations showed the fish schooled and aggregated near surfaces and behaviour seemed relatively normal. However, the marine release fish were exposed to more bird and fish predation. Feeding may have been re-initiated more slowly at the marine site compared to estuarine locations. Mortality of cage-held chinook was highest (est. 9%) at the marine location, as at all other sites mortality was <1%. Seawater challenge tests indicated that the chinook were smolted and "ready for sea", but evidence from other sources (caged fish studies and histological data) suggested that smoltification was incomplete. Beach seine data obtained up to 4 days after the releases showed that marine fish did not disperse to the Campbell River estuary. Transition zone fish had the widest apparent dispersal pattern, while estuarine fish displayed the most restricted distribution and were only taken at one station outside the estuary. Returns of marked fish will be monitored in the commercial and sport fishery and spawners will be sought in spawning ground surveys. From these data it should be possible to compute mortality rates for the marked groups released to the various habitats.

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Table. 1 Tag codes, release zones and site description for juvenile chinook releases on April 21, 1983. All depths and distances are approximate measurements. See Fig. 1 for locations.

Code	Zone	Release Site
8 22 07 08 09	River	In pool behind counting fence on Quinsam River at Quinsam Hatchery. Water depth 2-3 m. River width 50 m. Overhanging trees on right bank.
8 22 10 11 12	Estuarine	Baikie's Slough, est. 100 m from north junction of Campbell River. Water depth 3-4 m. Eelgrass (Zostera sp.) along bottom. Float and boat house 30 m north of release site. Slough width 60 m.
8 22 14 15 19	Transition	"Painter's Channel", approx. 650 m northwest of tip of spit at mouth of river; off Painters Lodge. Water depth 2-3 m, Eelgrass (Zostera sp.) along bottom. Channel width 30 m.
8 22 16 17 18	Marine	Deepwater Bay approximately 15 km north of mouth of river. Water depth 2-3 m. Sand bottom. Steep drop off 20 m north and east of drop site.

Table 2. Tag retention of marked fish.

Release zone	No. sampled	No. with adipose only	No. marked	% loss
River	300	15	285	5.00[1]
Estuarine	300	6	294	2.00[2]
Transition	300	12	288	4.00[3]
Marine	300	4	296	1.33[4]

[1]Retention measured over 1 d
[2]Retention measured over 4-6 d
[3]Retention measured over 2-3 d
[4]Retention measured over 6-8 d

Table 3. Number of fish tagged, removed for experimental purposes, and mortalities. Not included with the mortalities are 93 fish without pins.

Release zone	Tag code	No. marked	Mortalities[1]	No. removed	No. released
River	08 22 07	11800	24	73	11703
	08	11802	64	101	11637
	09	11800	98	82	11620
	No pin			27	
Estuarine	10	11852	56	128	11668
	11	12120	87	103	11930
	12	11885	11	118	11756
	No pin			13	
Transition	14	11800	17	103	11680
	15	11800	117	101	11582
	19	11800	50	105	11645
	No pin			35	
Marine	16	11817	61	88	11668
	17	11793	16	102	11675
	18	11868	4	104	11760
	No pin			12	

[1]An additional 120 mortalities due to handling just after tagging were recorded, but CWTs were not decoded.

Table 4. Lengths and weights of juvenile chinook prior to release (sampled from troughs) and after 3 weeks holding in cages at the four habitats.

Group	Initial length (mm)	S.D.	Sample size	Final length (mm)	S.D.	Sample size
River	68.9	6.32	150	70.6	5.53	43
Estuarine	69.5	6.75	150	71.0	5.79	117
Transition	65.2	8.45	136	70.7	6.33	114
Marine	65.3	6.51	148	70.7	5.80	102

Group	Initial weight (g)	S.D	Sample size	Final weight (g)	S.D	Sample size
River	3.73	1.00	150	3.91	0.94	43
Estuarine	3.58	1.01	150	3.82	0.90	117
Transition	3.18	1.18	136	4.17	1.04	114
Marine	3.14	0.93	148	3.69	0.88	102

Table 5. Transport time and related information for movement of marked chinook by helicopter on April 21, 1983.

Release Zone	Drop number	Time Out of hatchery (PST)	Time of release	Elapsed time (min)	Time in hatchery	Comments
Marine (Deepwater Bay)	1	1010	1028	18	1112	Fish for cage studies removed from bucket at Browns Bay parking lot. Helicopter refueled and returned to hatchery.
	2	1157	1210	13	1222	
Estuarine (North Baikie Mouth)	1	1235	1347	12	1205	Fish for cage studies removed from bucket at Tyee Spit helicopter pad. Helicopter refueled.
	2	1311	1325	14	1325	
Transition (Painters Channel)	1	1327	1340	13	1345	Fish for cage studies removed from bucket at Tyee Spit helicopter pad.
	2	1347	1400	13	1420	Helicopter refueled.
River (Quinsam River)	1	1425	1436	11	1438	Fish for cage studies removed from bucket at river beach.
	2	1441	1452	11		Helicopter return to Vancouver.

Table 6. Stomach contents of Buffalo sculpin (Enophrys bison) caught on April 21, 1983, by beach seine at the marine zone release site (Deepwater Bay, Stn. 32) fish were caught within 3 h of the second release (see Table 5).

Sculpin No.	No. of chinook in stomachs	Sculpin No.	No. of chinook in stomachs
1	3	7	2
2	1	8	1
3	2	9	0
4	0	10	0
5	2	11	0
6	0	12	0

Table 7. Estimated numbers of marked chinook from the April 21 1983 release passing through the fence on Quinsam River above the hatchery. There were no mortalities among the enumerated fish. Data courtesy of Quinsam Hatchery staff. Enumerations were not done on April 22.

Date (1983)	Daily totals	Date (1983)	Daily Totals
April 22	"Thousands estimated"	May 24	54
24	126	25	27
25	1218	26	68
26	210	27	54
27	34	28	27
May 3	8	29	27
4	25	30	81
5	25	31	41
12	23	June 1	27
14	34	2	41
16	14	3	14
17	21		
18	14		
20	14		
21	35		
22	27		
23	14		

Table 8. Data on stomach contents of juvenile chinook recovered from beach seining at Discovery Passage April 21 to 25, 1983.

(a) Marine release - fish recovered in marine zone (locations all in vicinity of Seymour Narrows)

	Day 1	Day 2	Day 3	Day 4
Mean forage ratio	1.1%	0.6%	0.9%	0.7%
% empty	28.5	40.0	28.5	45.5
N	7	5	7	11

(b) Estuary, transition and river release fish recovered in estuarine zone (stations mainly inside Tyee spit).

	Day 1	Day 2	Day 4
Mean forage ratio	0.2%	0.6%	1.3%
% empty	77.8	12.5	0
N	9	24	20

Table 9. Observations of caged fish held at Quinsam River (river release) April 21 to May 11, 1983. Temperature data are daily means thermographs, provided courtesy of Quinsam hatchery staff. Blanks indicate data not available.

Date 1983	Time (PST)	Temp (°C)	Comments	Other
April 21	1425-1455	11.75		
April 22		11.75	20 fish removed	Fagerlund & McBride sampled
April 23		12.25	0 Mortalities	
			12 fish removed	Fagerlund & McBride sampled
April 24		11.25	0 Mortalities	
April 25		10.25	0 Mortalities	
April 26		11.00	0 Mortalities	
April 27	0900	10.50	0 Mortalities	
			possible hole in cage #1	
April 28		11.50	0 Mortalities	
			32 fish removed	Blackburn, Fagerlund & McBride sampled
April 29	0800	12.75	0 Mortalities. No fish in upper cage	
April 30	1410	13.50	0 Mortalities	
May 1	1106	13.00	0 Mortalities	
			6 fish collected for L-W	
May 2		12.50	not observed	
May 3	0750		0 Mortalities	
May 4	0935		0 Mortalities	
May 5	0950	12.75	0 Mortalities	
May 7		12.00	0 Mortalities	
May 8	0740	10.50	0 Mortalities	
May 9	0728	10.25	0 Mortalities	
			10 large hatchery chinook seen around the pens	
			Beaver chewed sticks around pens possible reason for hole in pen No. 1	
			22 fish missing.	
May 11		12.50	9 fish removed - all remaining fish (43) brought back to lab. Cages removed.	Fagerlund & McBride sampled

Table 10. Observations of caged fish held at Freshwater Marina (estuarine release) April 21 to May 11, 1983. Temperature and salinity data are from 0, 0.5, and 1.0 m depths. Blanks indicate data not available.

Date 1983	Time (PST)	Temp (°C)			Sal (‰)			Comments	Other
		0 m	0.5 m	1.0 m	0 m	0.5 m	1.0 m		
April 21	1235-1310	11.5	10.5	9.7	2.1	4.4	8.5	fish in bottom of pens	
April 22		8.0	8.5	8.7	4.3	5.0	7.2	0 Mortalities	
								13 fish removed	Fagerlund & McBride sampled
April 23								0 Mortalities	
								12 fish removed	Fagerlund & McBride sampled
April 24								0 Mortalities	
April 25								0 Mortalities	
April 26	1215	10.0			9.0			0 Mortalities	
April 27		11.0			0.5			0 Mortalities	
April 28								0 Mortalities	
								31 fish removed	Blackburn, Fagerlund & McBride sampled
April 29	0845							0 Mortalities	
April 30	1210	11.2		11.2	3.5		7.3	0 Mortalities	
May 1	0858							0 Mortalities	
								10 fish collected for L-W	
May 2	1845	10.6	10.2	11.0	0.2	0.5	1.4	0 Mortalities	
May 3	1005	11.1	10.5	10.3	3.3	5.4	9.0	0 Mortalities	
	1510	11.4	10.8	11.0	2.2	2.7	3.3		
	2015							0 Mortalities	
May 4	1020	11.3	11.4	10.7	3.2	5.8	6.7	0 Mortalities	
May 5	0730	9.3	9.5	9.5	1.9	4.6	12.2	0 Mortalities	
May 7	0730	8.8	8.9	9.7	2.6	7.2	14.7	0 Mortalities	
May 8	0720	8.8	9.0	9.2	3.0	4.4	9.6	1 Mortality	
May 9	0700	9.0	9.2	9.2	2.7	4.0	10.0	0 Mortality	
May 11								10 fish removed-all remaining fish (117) brought back to lab. Cages removed.	Fagerlund & McBride sampled

Table 11. Observations of caged fish held near Painters Lodge (transition release) April 21 to May 11, 1983. Temperature and salinity data are from 0, 0.5, and 1.0 m depths. Blanks indicate data not available.

Date 1983	Time (PST)	Temp (°C)			Sal (‰)			Comments	Other
		0 m	0.5 m	1.0 m	0 m	0.5 m	1.0		
April 21	1327-1350	9.7	9.6	9.8	3.9	3.7	4.9	fish in bottom of cages	
April 22								0 Mortalities	
								14 fish removed	Fagerlund & McBride sampled
April 23								0 Mortalities	
								9 fish removed	Fagerlund & McBride sampled
April 24								0 Mortalities	
April 25								0 Mortalities	
April 26	1300	12.5						0 Mortalities	
April 27	1130	12.5						0 Mortalities	
April 28								0 Mortalities	
								28 fish removed	Blackburn, Fagerlund & McBride sampled
April 29	0900	9.7		9.7	4.0		6.8	0 Mortalities	
April 30	1240	13.5		10.5	7.4		27.7	0 Mortalities	
May 1	0910	10.0		9.3	6.6		22.8	0 Mortalities	
May 2	1915	9.8	10.0	9.3	0.9	4.4	30.3	0 Mortalities	
May 3	1020	10.0	10.1	10.0	4.7	6.6	7.7	0 Mortalities	
								10 fish/cage for L-W	
	1445	11.9	10.8	9.9	4.9	21.0	28.4	0 Mortalities	
May 4	1235	10.9	10.8	10.8	3.3	3.8	4.5	0 Mortalities	
May 5	0755	9.6	9.2	9.2	6.5	29.9	29.9	0 Mortalities	
May 7	1250	10.0	10.3	9.6	6.4	6.7	29.5	0 Mortalities	
May 9	0855							0 Mortalities	
May 11								10 fish removed-all remaining fish (114) brought back to lab. Cages removed	Fagerlund & McBride sampled

Table 12. Observations of caged fish held at Browns Bay (marine release), April 21 to May 11, 1983. Temperature and salinity data are surface values. Blanks indicate data not obtained.

Date 1983	Time (PST)	Temp (°C)	Sal (‰)	Comments	
April 21	1010			0 Mortalities	
	1258			20 fish removed	Fagerlund & McBride sampled
April 22	1123			5 Mortalities	
				12 fish removed	Fagerlund & McBride sampled
April 23				3 Mortalities	
				12 fish removed	FAgerlund & McBride sampled
April 24				1 Mortality	
April 25				0 Mortalities	
April 26	1030	9.8		4 Mortalities	
April 27	1000	9.8		0 Mortalities-fish from previous day removed	
April 28				0 Mortalities	
				26 fish removed	Blackburn, Fagerlund & McBride sampled
April 29	0945		34.0	4 Mortalities-fish partially eaten	
April 30		8.0	34.0	0 Mortalities	
May 1	1000	9.0	32.0	0 Mortalities, 5 fish collected for L-W	
May 2				No observations made	
May 3	0850			0 Mortalities-no swelling	
				0 Mortalities	
	1950			0 Mortalities	
May 4	0830			0 Mortalities	
	1340			0 Mortalities	
May 5	0850			0 Mortalities	
May 7	0850			0 Mortalities	
May 8	0825			0 Mortalities	
May 9	0810			0 Mortalities	
May 11				10 fish removed-all remaining fish (57) brought back to lab. Cages removed. 21 fish missing-holes found in 2 cages.	Fagerlund & McBride sampled

Table 13. Results of seawater challenge tests [as described in Clark and Blackbourn 1977] with juvenile chinooks from cages held at the four release areas and from the hatchery pond. > indicates fish transferred from indicated salinity regime. FW indicates 0‰.

Date Collected 1983	Treatment	N	Length (mm) Mean	SE	Weight (g) Mean	SE	Condition Factor Mean	SE	Plasma Sodium (milliequivalents) N	Mean	SE
	Hatchery Pond										
April 12	FW	10	7.92	.10	4.88	.23	.98	.01	10	156.9	1.6
April 12	FW > 29‰	24	7.62	.15	4.51	.27	.98	.01	24	163.9	1.1
	Quinsam River Cages										
April 28	FW	4	7.05	.42	3.35	.60	.92	.02	4	156.1	1.1
April 28	FW > 29‰	16	6.90	.25	3.16	.27	.92	.02	16	171.8	2.2
	Freshwater Marina Cages										
April 28	FW	5	6.94	.33	3.30	.43	.96	.02	5	157.6	0.4
April 28	2 > 29‰	14	7.31	.09	3.72	.15	.95	.01	14	159.0	1.1
	Painter's Lodge Cages										
April 28	20‰	5	7.20	.17	3.48	.28	.92	.02	5	153.7	0.9
April 28	10 > 25‰	13	6.63	.15	2.75	.17	.93	.02	13	160.2	0.8
	Brown's Bay Cages										
April 28	29>29‰	26	6.98	.15	3.33	.24	.96	.03	15	158.3	0.7

Table 14. Plasma cortisol concentrations (ng/ml), interrenal cell nuclear diameters (ICND) and haematocrits (%) of juvenile chinook before and after transport to holding cages. Values are means ± SD. Cortisol concentrations and haematocrits were determined on 6-13 fish. ICND values were obtained by taking 25 readings from each of 8 fish.

	In hatchery troughs	After transport	1 day in cages	2 days in cages	7 days in cages	20 days in cages
River						
Cortisol	70.6^{abc}* ± 32.5	86.0^{abcd} ± 40.5	58.3^{abc} ± 35.9	102.8^{bcd} ± 42.5	18.6 ± 10.0	46.1^{abc} ± 19.9
ICND	6.090^{cde} ± 0.168	6.100^{cde} ± 0.157	6.120^{de} ± 0.165	6.158^{e} ± 0.209	6.122^{de} ± 0.202	5.937^{ab} ± 0.189
Haematocrit	-	-	40.2^{b} ± 4.6	36.3^{a} ± 4.3	36.8^{a} ± 4.0	38.0^{a} ± 3.2
Estuarine						
Cortisol	-	-	31.1^{abc} ± 26.4	26.2^{ab} ± 17.5	47.3^{ab} ± 21.3	72.4^{abc} ± 31.2
ICND	-	-	6.093^{cde} ± 0.195	6.084^{cde} ± 0.156	6.033^{bcd} ± 0.179	4.909^{a} ± 0.196
Haematocrit	-	-	32.4^{a} ± 3.4	34.1^{a} ± 2.8	34.8^{a} ± 2.8	36.9^{a} ± 4.0
Transition						
Cortisol	-	-	52.4^{abc} ± 19.6	61.9^{abc} ± 35.3	23.8^{ab} ± 4.6	37.8^{abc} ± 22.8
ICND	-	-	6.087^{cde} ± 0.137	6.071^{cde} ± 0.154	6.089^{cde} ± 0.197	6.062^{cde} ± 0.158
Haematocrit	-	-	37.2^{b} ± 3.8	33.6^{a} ± 3.2	36.2^{a} ± 2.9	38.9^{a} ± 3.2
Marine						
Cortisol	153.4^{de} ± 111.6	113.5^{cd} ± 47.8	229.9^{e} ± 99.3	92.3^{bcd} ± 89.7	40.6^{ab} ± 13.0	21.5^{a} ± 5.4
ICND	-	6.063^{cde} ± 0.156	6.121^{de} ± 0.147	6.139^{e} ± 0.219	6.075^{cde} ± 0.190	6.007^{abc} ± 0.191
Haematocrit	-		33.8^{a} ± 4.8	33.8^{a} ± 4.8	34.4^{a} ± 5.3	36.6^{a} ± 4.2

* Results of ANOVA's are given in the text. Superscripts denote results of either Tukey's multiple range test (cortisol or ICND, all values) or pairwise comparison of locations by t-tests (haemotocrit). Values carrying a common letter are not statistically different ($p = 0.05$).

Table 15. Stomach contents of juvenile chinook held in cages at Quinsam River. Fish were put in cages April 21, 1983.

Date Collected 1983	Length (mm)	Weight (g)	Content weight (g)	% of body weight	Adult Diptera	Insect remains	Trichoptera larva	OMP	Wood
May 5	60	2.5	0.0107	0.43		+	1		
May 5	65	3.3	0.0176	0.53		+			
May 5	71	4.6	0	0					
May 5	72	4.3	0	0					
May 5	78	5.6	0	0					
May 11	75	4.1	0.0030	0.07	2				
May 11	67	3.2	0.0050	0.16		+			
May 11	65	3.3	0.0096	0.29		+			
May 11	77	4.8	0.0089	0.19		+			+
May 11	66	3.4	0.0203	0.60	1			+	+

Table 16. Stomach contents of juvenile chinook held in cages at Freshwater Marina (estuary site). Fish were put in cages April 21, 1983

Date Collected 1983	Length (mm)	Weight (g)	Content weight(g)	% of body weight	Adult Dipterans	Adult Insect remains	Insect parts	Unid Gammarid	Sphaeromid Isopods	Unid Calanoids	Wood	Unid Mush
May 1	68	3.8	0.0286	0.75		+		2				
May 1	65	3.3	0.0059	0.18		+						
May 1	74	5.0	0.0115	0.23		+		1		2		
May 1	80	6.1	0	0								
May 1	75	5.2	0	0								
May 11	73	3.9	0.0322	0.83					1		++	
May 11	70	3.8	0.0086	0.23			+				+	
May 11	68	3.4	0.0291	0.86					2			+
May 11	63	1.9	0.0018	0.09			+					
May 11	65	3.2	0.0378	1.18	1			1	5			

Table 17. Stomach contents of juvenile chinook held in cages near Painters Lodge (transition site). Fish were put in cages April 21, 1983.

Date Collected 1983	Length (mm)	Weight (g)	Content weight(g)	% of body weight	Adult Diptera	unid Calanoids	Juvenile Calanoids	Copepod larvae	Cumella sp	Unid Cumacean	Harpacticoids	Bosmina sp	Nematode
May 3	71	4.4	0.0139	0.32		1		1		2		5	
May 3	70	4.5	0.0213	0.47		7	7		13		2	6	
May 3	78	5.9	0.0095	<0.01					2				
May 3	72	4.3	0.0038	0.89						1		1	1
May 3	71	4.0	0.0055	0.14	+	1				1			
May 11	77	5.3	0.0381	0.15		3							
May 11	67	3.7	0.0071	0.19		5			2		1		
May 11	69	4.1	0.0121	0.30		7			1				
May 11	81	6.4	0	0									
May 11	69	3.9	0	0									

Table 18. Stomach contents of juvenile chinook held in cages at Browns Bay (marine site). Fish were put in cages April 21, 1983.

Date Collected 1983	Length (mm)	Weight (g)	Content weight (g)	% of body weight	Calanoids	Harpacticoids	Hyperidae	Crab larvae	Barnacle Cyprids
May 5	56	2.1	0.0118	0.56				10	2
May 5	66	2.8	0.0092	0.33	25			6	
May 5	64	2.5	0.0092	0.36	5			5	3
May 5	64	2.6	0.0166	0.07	23	1		7	
May 5	72	3.5	0.0047	0.13				8	
May 11	75	4.4	0.0389	0.88	25		1		
May 11	77	4.6	0.0399	0.87	27	1	1	2	
May 11	77	4.6	0.0173	0.38	19			4	
May 11	73	4.1	0.0740	0.80	3			4	
May 11	85	6.4	0.1922	0.19	24	21			

FIGURES

Fig. 1. Study area, showing release sites at Quinsam River, estuary release site (Baikie's Slough; Stn. 7), transition release site (Painters Lodge; Stn. 34), and marine release site (Stn. 32; Deepwater Bay). Fish were held in cages at Quinsam River, at a marina near Stn. 7, on a float near Stn. 34, and at a marina in Browns Bay.

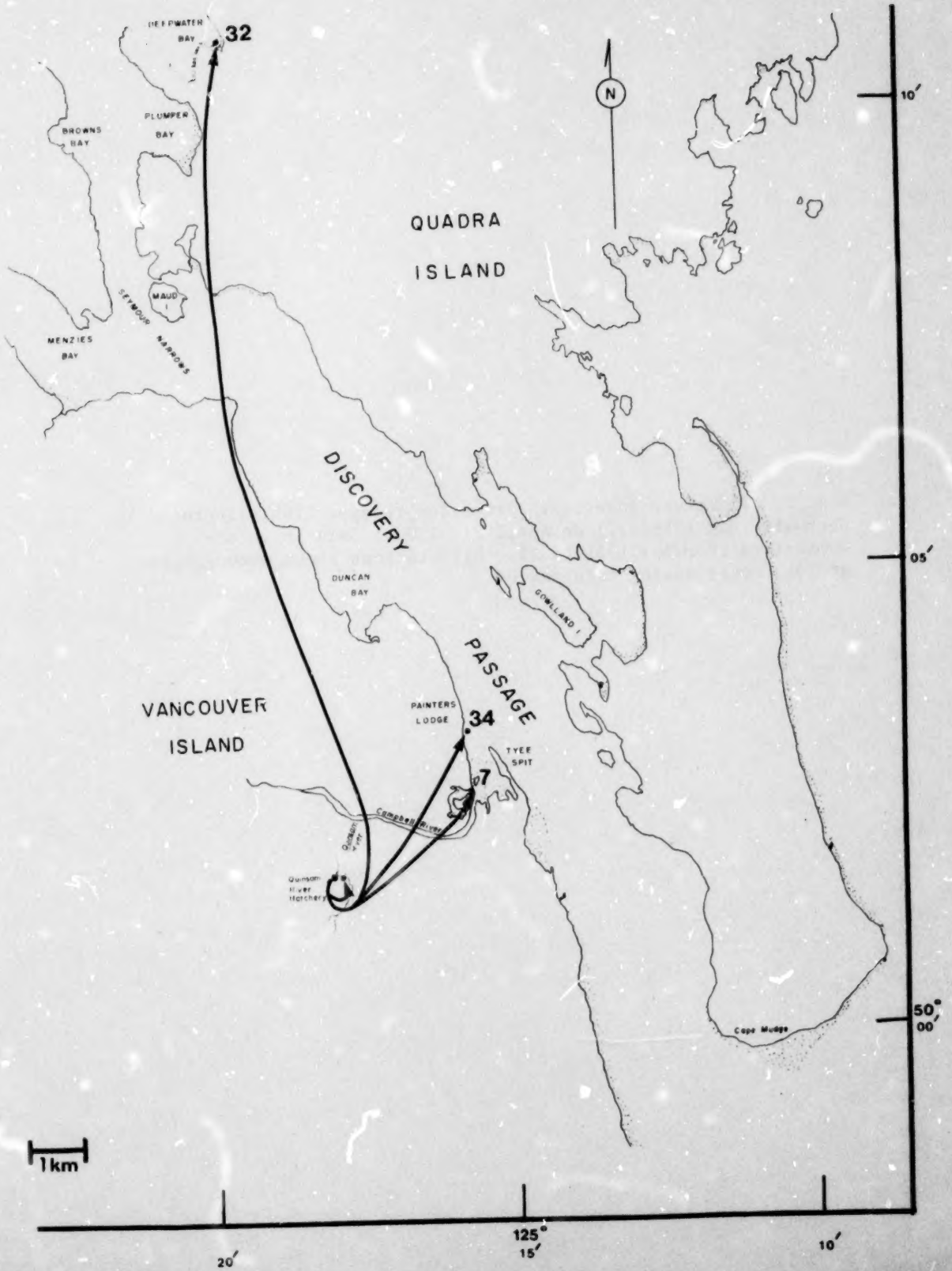

DEEPWATER BAY
32
PLUMPER BAY
BROWNS BAY
MAUD I.
SEYMOUR NARROWS
MENZIES BAY
QUADRA ISLAND
N
10'
DISCOVERY
DUNCAN BAY
GOWLLAND I.
05'
PASSAGE
VANCOUVER ISLAND
PAINTERS LODGE
34
TYEE SPIT
7
Campbell River
Quinsam River Hatchery
Cape Mudge
50° 00'
1km
20'
125° 15'
10'

Fig. 2. Recapture locations for marine release fish, liberated at Deepwater Bay (Stn. 32) on April 21, 1983. Data shown are summarized from April 21 to 25. All stations shown were sampled at least once during this period.

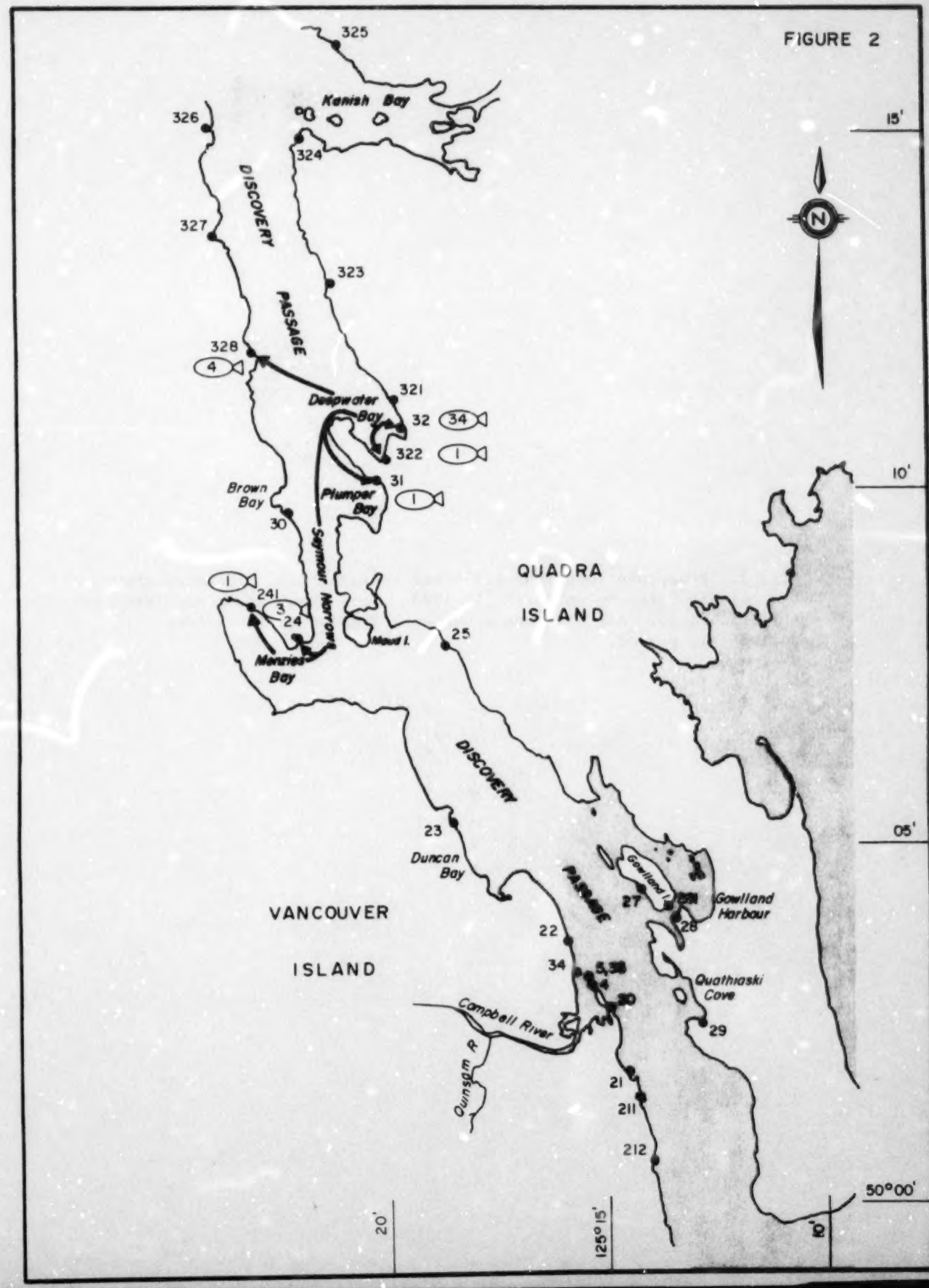


FIGURE 2
325
Kanish Bay
326
324
DISCOVERY
PASSAGE
327
323
328
4
321
Deepwater Bay
32
34
322
1
31
1
Brown Bay
Plumper Bay
30
Seymour Narrows
1
241
3
24
Maud I.
25
Menzies Bay
QUADRA
ISLAND
DISCOVERY
23
Duncan Bay
PASSAGE
Gowlland I.
27
Gowlland Harbour
28
VANCOUVER
ISLAND
22
34
Quathiaski Cove
Campbell River
29
Oyster R.
21
211
212
15'
10'
05'
50°00'
20'
125°15'
10'
N

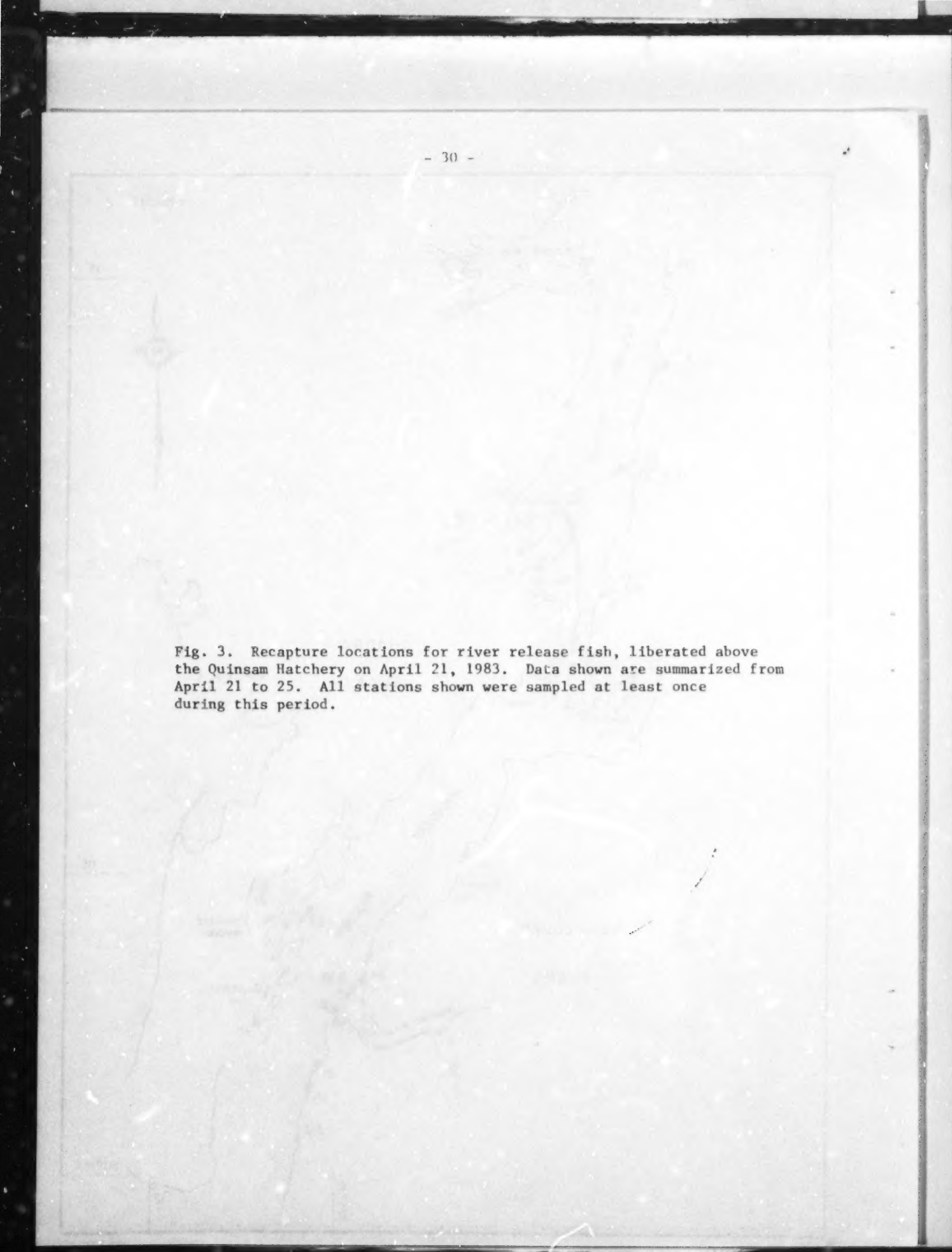


Fig. 3. Recapture locations for river release fish, liberated above the Quinsam Hatchery on April 21, 1983. Data shown are summarized from April 21 to 25. All stations shown were sampled at least once during this period.

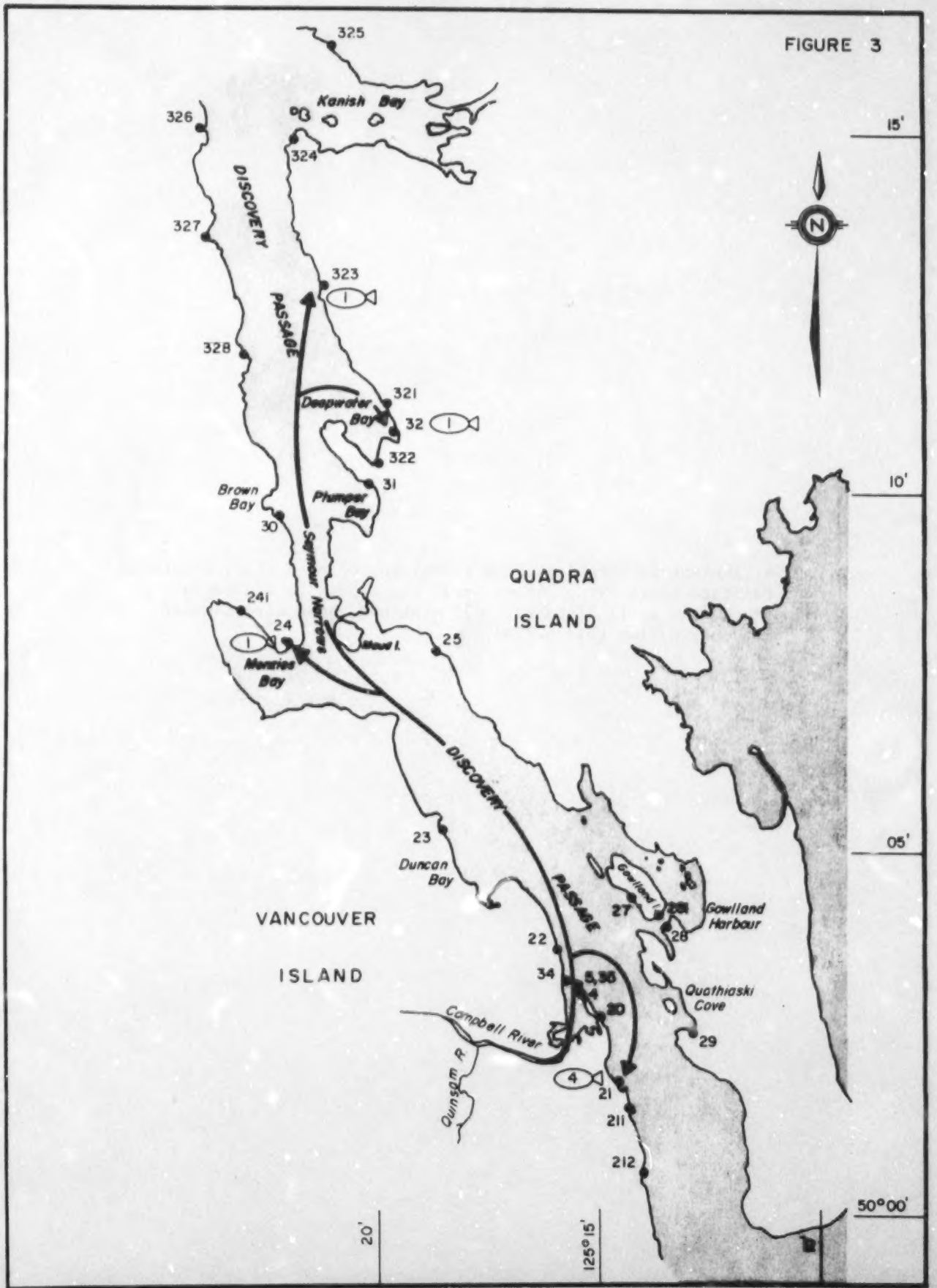


FIGURE 3
325
Kanish Bay
326
324
DISCOVERY
327
323
PASSAGE
328
321
Deepwater Bay
32
322
31
Brown Bay
Plumper Bay
30
Seymour Narrows
241
24
Maud I.
25
Menzies Bay
QUADRA ISLAND
DISCOVERY
23
Duncan Bay
PASSAGE
Gowlland I.
27
28
Gowlland Harbour
VANCOUVER ISLAND
22
34
35,36
Quathiaski Cove
Campbell River
29
Quinsam R.
21
211
212
15'
10'
05'
50°00'
20'
125°15'

Fig. 4. Recapture locations from transition release fish, liberated near Painters Lodge (Stn. 34) on April 21, 1983. Data shown are summarized from April 21 to 25. All stations shown were sampled at least once during this period.

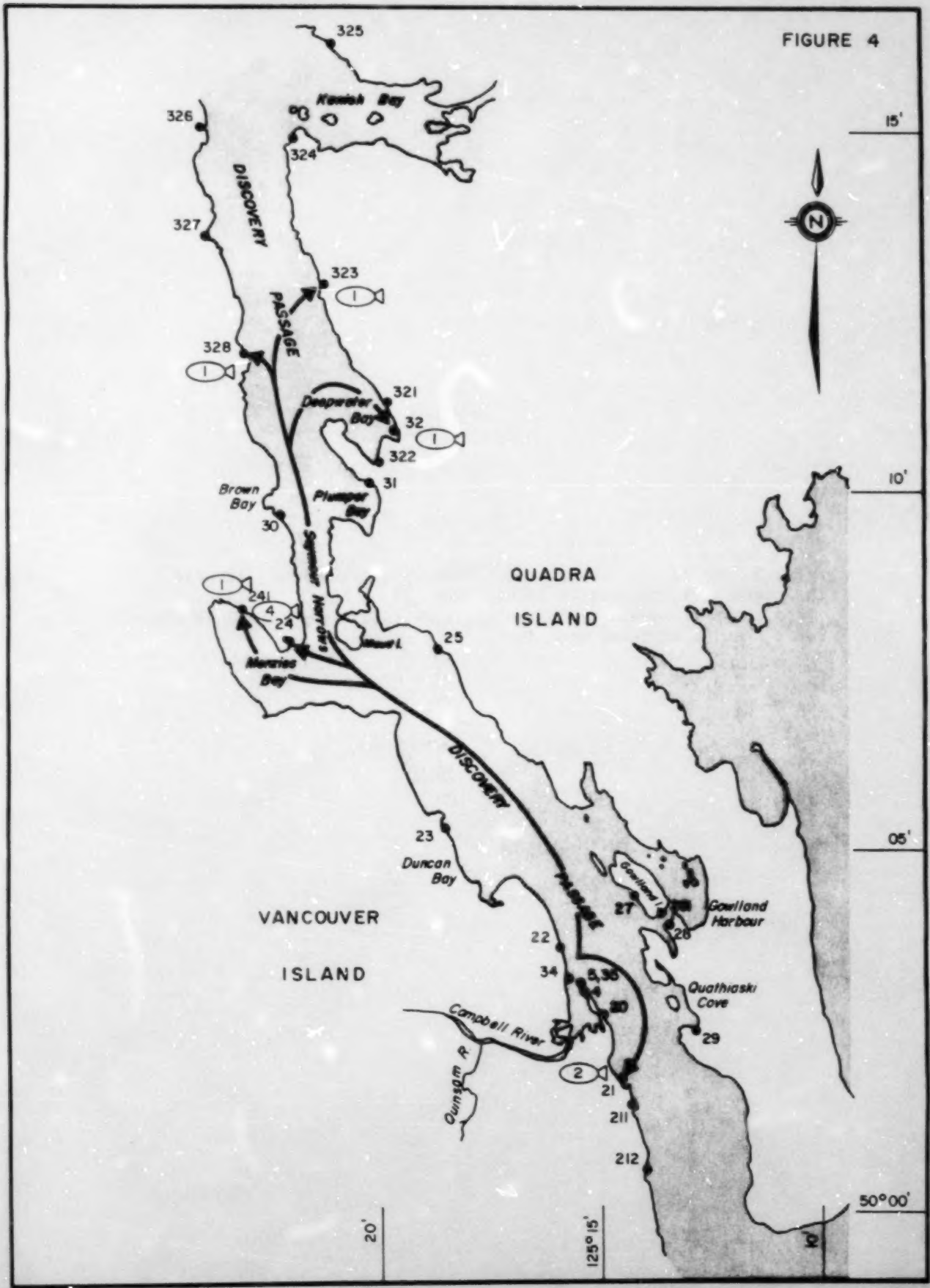


FIGURE 4
325
Kanish Bay
326
324
DISCOVERY
327
PASSAGE
323
328
Deepwater Bay
321
32
322
31
Brown Bay
Plumper Bay
30
Seymour Narrows
241
24
Menzies Bay
Mitchell I.
25
QUADRA
ISLAND
DISCOVERY
PASSAGE
23
Duncan Bay
VANCOUVER
ISLAND
Gowlland I.
27
Gowlland Harbour
28
22
34
35
Quathiaski Cove
Campbell River
29
Quinsam R.
21
211
212
15'
10'
05'
50°00'
20'
125°15'
10'

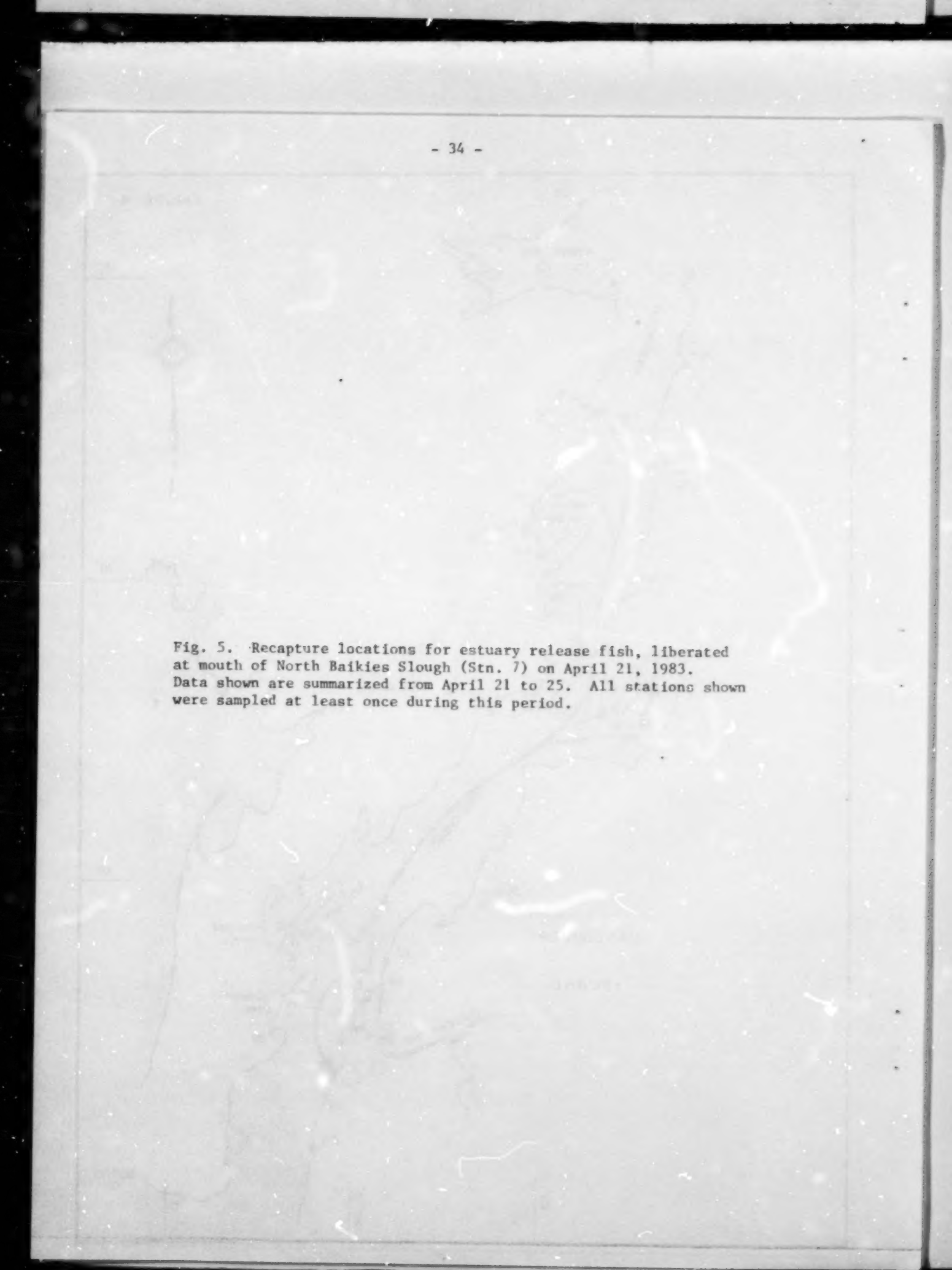
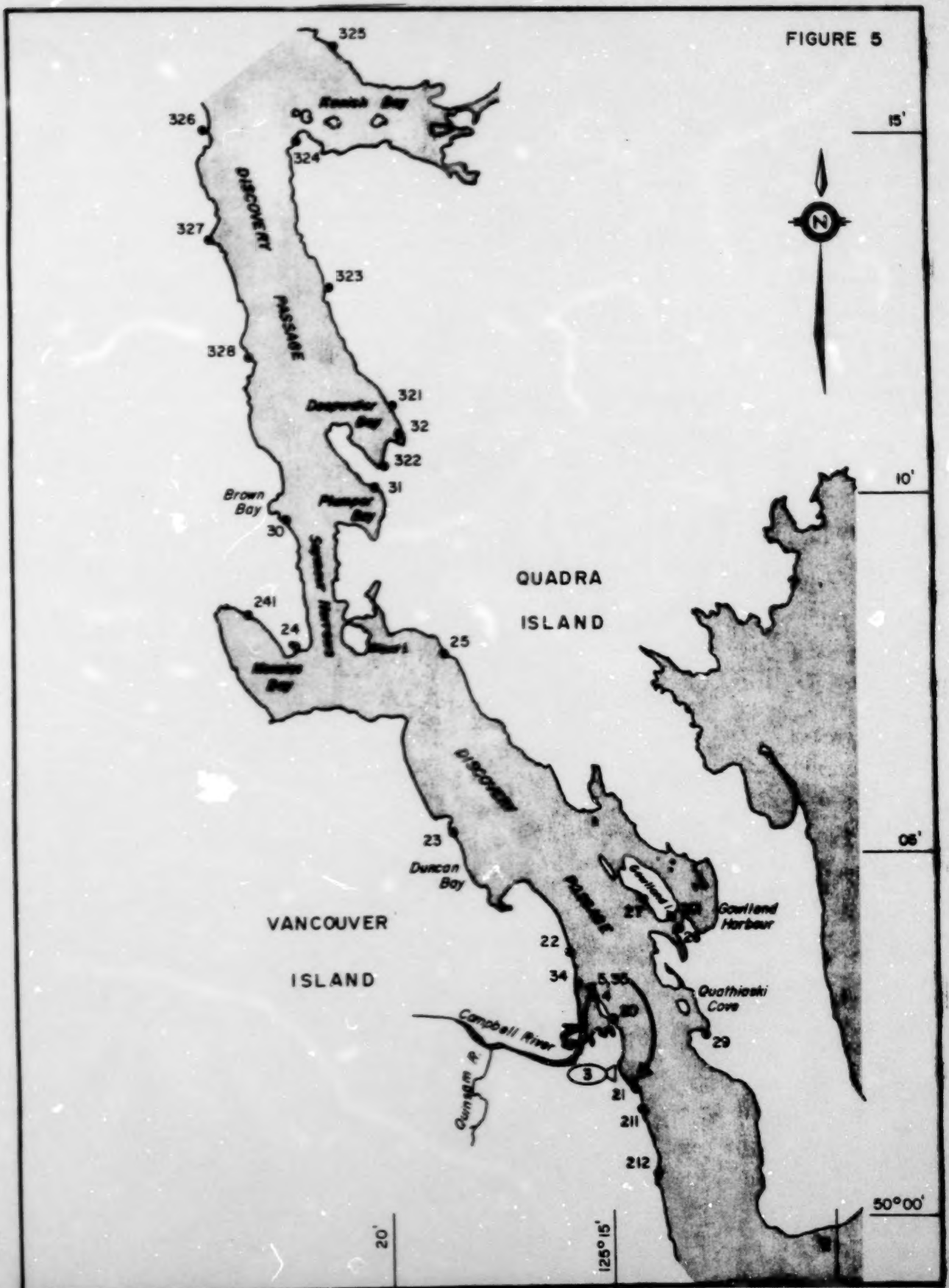


Fig. 5. Recapture locations for estuary release fish, liberated at mouth of North Baikies Slough (Stn. 7) on April 21, 1983. Data shown are summarized from April 21 to 25. All stations shown were sampled at least once during this period.

FIGURE 5


325
326
324
327
323
328
321
32
322
31
30
241
24
25
23
22
34
21
211
212
29
3
DISCOVERY PASSAGE
Brown Bay
Duncan Bay
QUADRA ISLAND
VANCOUVER ISLAND
Campbell River
Quathiaski Cove
Gowland Harbour
15'
10'
05'
50°00'
20'
125°15'
N